ORIGINAL ARTICLE

Insomnia is more common among subjects living in damp buildings

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Background: Insomnia is a condition with a high prevalence and a great impact on quality of life. Little is known about the relation between and sleep disturbances and the home environment.
Aim: To analyse the association between insomnia and building dampness.
Methods: In a cross-sectional, multicentre, population study, 16 190 subjects (mean age 40 years, 53% women) were studied from Reykjavik in Iceland, Bergen in Norway, Umeå, Uppsala, and Göteborg in Sweden, Aarhus in Denmark, and Tartu in Estonia. Symptoms related to insomnia were assessed by questionnaire.
Results: Subjects living in houses with reported signs of building dampness (n = 2873) had a higher prevalence of insomnia (29.4 *v* 23.6%; crude odds ratio 1.35, 95% CI 1.23 to 1.48). The association between insomnia and different indicators of building dampness was strongest for floor dampness: ''bubbles or discoloration on plastic floor covering or discoloration of parquet floor'' (crude odds ratio 1.96, 95% CI 1.66 to 2.32). The associations remained significant after adjusting for possible confounders such as sex, age, smoking history, housing, body mass index, and respiratory diseases. There was no significant difference between the centres in the association between insomnia and building dampness.
Conclusion: Insomnia is more common in subjects living in damp buildings. This indicates that avoiding dampness in building constructions and improving ventilation in homes may possibly have a positive effect on the quality of sleep.

Insomnia is a condition with a high prevalence[1–3] and a great impact on quality of life.[4] Previous studies have shown that insomnia is related to lifestyle factors such as smoking and excessive use of alcohol,[2 5 6] as well as somatic and psychiatric disorders.[2 7–9] In medical textbooks it is recommended that the bedrooms should be well ventilated and have a comfortable temperature,[10] but scientific investigations on the relation between the home environment and sleep disturbances are lacking. This is somewhat surprising since most people sleep eight hours at night, which is a large part of the time spent at home.

Several studies have found that living in a home with mould or water damage increases the risk of respiratory symptoms such as wheeze, asthma, and mucosal irritation of the upper airways.[11–14] An association between sleep disturbances and building dampness has, however, to our knowledge only been reported in one previous study.[15]

The aim of this study was to analyse the association between insomnia and indicators of building dampness in population based samples in the Nordic countries.

METHODS

This is a cross-sectional analysis of a follow up study.

Population

The Respiratory Health in Northern Europe (RHINE) is a follow up study of participants from seven Northern European centres who participated in the European Community Respiratory Health Survey (ECRHS) stage 1, in 1990–94.[16] In stage 1 of the ECRHS, men and women, aged 20–44 years, were randomly selected from the population registers of each participating centre. A postal questionnaire was sent to 3000–4000 subjects in each centre. The target population for the RHINE study was all subjects from Reykjavik in Iceland, Bergen in Norway, Umeå, Uppsala, and Göteborg in Sweden, Aarhus in Denmark, and Tartu in Estonia that participated in stage 1 of the ECRHS (n = 21 802, response rate 83.7%). The eligible subjects were sent a postal questionnaire in 1999–2001. Two reminders were sent to subjects not responding to the first mailing. In total 16 190 (74.2%) subjects answered the questionnaire. The informed consent of all participants was obtained and the study was approved by all the local ethics committees.

Questionnaire

The first part of the questionnaire contained 12 questions identical to those asked in the ECRHS stage 1, including questions on respiratory symptoms, asthma, rhinitis, and gender. The second part contained 52 questions covering various aspects such as bronchitis, smoking, indoor environment, and sleep disorders. The seven questions on sleep disorders were derived from the Basic Nordic Sleep Questionnaire.[17] The questions have previously been used in four of the ECRHS centres[1 18] and have been published as an appendix in a previous report.[1] The subjects were asked to estimate the frequency of different symptoms during the last months on a five point scale: 1, never; 2, less than once a week; 3, 1–2 nights per week; 4, 3–5 nights per week; and 5, almost every night.

Insomnia

The three aspects of insomnia analysed in this investigation were *difficulty inducing sleep* (DIS), *difficulty maintaining sleep* (DMS), and *early morning awakenings* (EMA). DIS was defined as ''difficulty in falling asleep at night'', DMS as ''waking up repeatedly during the night'', and EMA as ''waking up too early and having difficulty in getting to sleep again''. For all three symptoms a frequency of at least three nights per week

Main messages

- The prevalence of insomnia is higher in subjects living in homes with building dampness.
- This association remains after adjusting for possible confounders such as smoking, respiratory diseases, and type of housing.

Policy implication

- Avoiding dampness in building constructions and improving ventilation in homes may have a positive effect on the quality of sleep.

was used as the cut off point. *Insomnia* was defined as reporting at least one of the three symptoms defined above.

Home environment

The questions on building characteristics have been used in several previous investigations[11 14] and have been validated against direct observations by an occupational hygienist.[11] *Water damage* was defined as having observed ''water leakage or water damage indoors in walls, floors, or ceilings''. *Visible moulds* was defined as having observed ''visible mould growth indoors on walls, floors, or ceilings''. *Floor dampness* was defined as having observed ''bubbles or yellow discoloration on plastic floor covering, or black discoloration of parquet floor''. *Building dampness* was defined as reporting at least one of the three indicators defined above. The recall period was 12 months. In addition the subjects were asked to specify type and age of housing.

Socioeconomic index

A socioeconomic index was created using information on current occupation in four of the seven centres (Bergen, Göteborg, Uppsala, and Tartu). Based on this information the subjects were divided in to the following categories:

I. ''Managers and professionals; non-manual'' (legislators, senior officials, managers, and professional)
II. ''Other non-manual'' (technicians and associate professionals, clerks, service workers, and market sales workers)
III. ''Skilled manual'' (skilled agricultural and fishery workers and craft and related trades workers)
IV. ''Semi-skilled or unskilled manual'' (plant and machine operators and assemblers and elementary occupations)
V. ''Unclassifiable or unknown'' (housewife, student, not classifiable job, unemployed, not working because of poor health and retired).

Other explanatory variables

Smoking history was assessed by two questions: ''Are you a smoker (this applies even if you only smoke the odd cigarette/cigar or pipe every week)?'' and ''Are you an ex-smoker?''. The subjects were categorised into three groups: never smokers, ex-smokers, or current smokers.

Body mass index (BMI) was calculated from the subjects' self-reported height and weight: (weight in kg)×(height in metres)$^{-2}$.

Asthma was defined as a positive answer to both of the questions: ''Do you have or have you ever had asthma?'' and ''Have you ever had asthma diagnosed by a doctor?''.

Allergic rhinitis was defined as a positive answer to the question: ''Do you have any nasal allergies including hay fever?''.

Chronic bronchitis was defined as a negative answer to both asthma questions above and positive answers to all three of the following questions: ''Do you usually bring up phlegm or do you have phlegm in your airways which you have difficulty bringing up?'', ''Do you bring up phlegm in this way almost daily at least three months every year?'', and ''Have you had this kind of problem for at least two years in a row?''.

Statistics

The statistical analysis was performed using Stata 7.0 and 8.0 (Stata Corporation, College Station, Texas). The χ^2 test and unadjusted logistic regression were used when comparing subjects with different household conditions in the univariate analyses. To study the influence of different explanatory variables on insomnia, adjusted odds ratios (OR) were calculated by multiple logistic regression. The choice of the non-environmental explanatory variables was based on experience from previous studies of insomnia.[1 2] In these analyses the indicators of building dampness were included separately in the analyses. The adjusted OR was analysed on pooled data from all seven centres, adjusting for centre. In order to detect heterogeneity between centres in the relation between insomnia and building dampness, the adjusted OR

Table 1 Characteristics of the study populations and prevalence of insomnia related symptoms

	Reykjavik (n = 1969)	Bergen (n = 2506)	Umeå (n = 2640)	Uppsala (n = 2572)	Göteborg (n = 2188)	Aarhus (n = 2607)	Tartu (n = 1708)	All subjects (n = 16190)
Response rate	67.8	72.6	80.2	81.8	76.0	71.0	69.4	74.2
Age, years	41 (7)	41 (7)	41 (7)	40 (7)	40 (7)	39 (7)	36 (7)	40 (7)
Women	54.6	51.9	51.5	52.5	54.2	52.2	56.1	53.0
Ex-smokers	31.5	24.5	26.2	26.1	25.6	34.6	17.1	25.1
Current smokers	30.9	38.5	19.2	19.6	29.5	34.6	35.3	29.3
Detached house	28.6	49.4	57.5	42.7	34.8	47.9	25.9	42.5
Semi-detached house	25.7	21.1	11.3	12.8	17.3	15.3	2.6	15.3
Apartment	45.7	29.5	31.2	44.5	47.9	36.8	71.5	42.2
Building dampness (at least one indicator)	22.7	16.4	13.9	14.6	12.1	18.8	31.6	17.9
Water damage	20.1	13.4	9.8	9.1	7.7	14.4	23.4	13.4
Visible moulds	6.6	4.5	3.5	6.2	4.5	10.1	13.6	6.7
Floor dampness	6.4	2.2	5.4	4.1	4.5	2.2	2.6	3.8
Insomnia (at least one symptom)	25.0	22.3	26.5	24.6	32.0	21.4	22.2	24.8
Difficulty inducing sleep	6.8	8.9	7.9	6.5	11.2	6.0	7.9	7.8
Difficulty maintaining sleep	18.3	16.0	20.8	19.8	24.5	16.4	15.5	18.8
Early morning awakenings	9.5	8.2	8.6	9.1	11.2	7.4	9.2	8.9

Results expressed as % and mean (SD).

was calculated separately in each centre. An average effects estimate was derived, and potential heterogeneity between centres was examined using standard methods for random effects meta-analysis.[19]

RESULTS

Table 1 presents the response rate and characteristics of the subjects of the different centres. The non-responders were somewhat younger (31 (7) *v* 32 (7) years of age in the ECRHS I 1990–94; $p < 0.001$), more often men (54.0 *v* 46.7%; $p < 0.001$), and had at baseline a lower prevalence of allergic rhinitis (18.4 *v* 20.8%; $p < 0.01$) than the responders. In Tartu the age of the subjects at the follow up was significantly lower than in the other centres due to the fact that the ECRHS I was performed some years later in Tartu than the other centres (36 (7) *v* 40 (7) years, p 0.001). The highest prevalence of all three insomnia related symptoms was found in Göteborg (table 1).

Building dampness was reported by 2873 subjects (17.9%) in the investigation. Subjects that lived in homes with signs of building dampness were significantly younger, and more often women and current smokers than subjects not reporting building dampness. Subjects that reported building dampness were also more often living in apartments and older buildings than subjects that did not report building dampness (table 2).

Subjects living in homes with dampness had a significantly higher prevalence of insomnia and all three insomnia related symptoms (table 2). A significantly higher prevalence of insomnia was found for all three indicators of building dampness (fig 1). No significant trend was found between building age and the prevalence of insomnia.

Living in homes with signs of building dampness was an independent risk factor of insomnia and insomnia related symptoms even after adjustment for sex, age smoking history, and housing and building age (tables 3 and 4). Other risk factors for insomnia were female gender, being an ex-smoker or current smoker, and living in an apartment (table 3). The risk of insomnia also increased with increasing BMI (OR 1.03, 95% CI 1.02 to 1.04) and was higher in subjects with allergic rhinitis (OR 1.26, 95% CI 1.15 to 1.39), asthma (OR 1.72, 95% CI 1.50 to 1.98), and chronic bronchitis (OR 2.17, 95% CI 1.81 to 2.59) than in subjects without these disorders. No significant interaction between insomnia and building dampness was found in relation to sex, smoking, or type of housing.

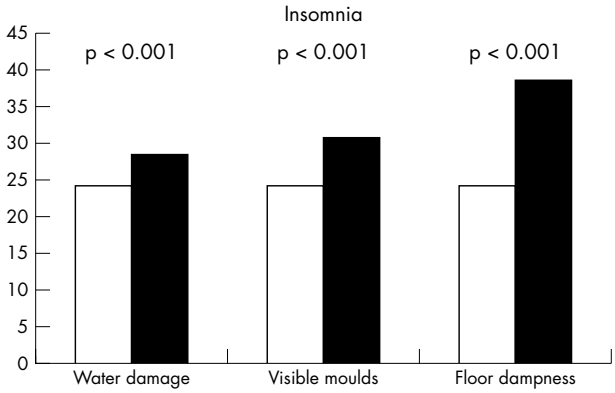

Figure 1 The prevalence of insomnia in subjects living in homes without (open bars) and with (shaded bars) indicators of building dampness.

The association between insomnia and building dampness remained significant after adjusting for socioeconomic status (OR 1.39, 95% CI 1.21 to 1.60) in the subpopulation of 7100 subjects where this information was available.

The association between building dampness and insomnia was assessed by meta-analysis in order to detect heterogeneity between the centres (fig 2). Meta-analyses were also performed for the association of the other indicators of building dampness and insomnia. In all analyses the estimates were almost identical to those derived when analysing the pooled data, and no significant centre heterogeneity was detected ($p > 0.30$).

DISCUSSION

The main finding in this analysis is that insomnia related symptoms were more common in subjects living in houses with building dampness. This relation remained significant after adjusting for other possible confounders such as smoking, type of housing, and respiratory disorders.

The association between insomnia and building dampness is a novel finding which may be of large importance from a public health perspective given the high prevalence and

Table 2 Characteristics of the study populations and prevalence of insomnia related symptoms in relation to reported building dampness

	No building dampness (n = 13154)	Building dampness (n = 2872)	p value
Age, years	40.1 (7.3)	38.5 (7.2)	<0.001
Women	52.2	57.0	<0.001
Smoking history			<0.001
Never smokers	46.3	42.9	
Ex-smokers	25.1	25.2	
Current smokers	28.6	31.9	<0.001
Type of housing			<0.001
Detached house	44.2	35.2	
Semi-detached house	15.6	14.4	
Apartment	40.3	50.4	
Age of housing			<0.001
0–10 years	14.2	9.0	
11–20 years	20.0	17.5	
21–40 years	33.6	35.8	
41–60 years	15.4	17.0	
More than 60 years	16.7	20.7	
Insomnia (at least one symptom)	23.6	29.4	<0.001
Difficulty inducing sleep	7.3	10.0	<0.001
Difficulty maintaining sleep	17.8	22.4	<0.001
Early morning awakenings	8.6	10.4	0.002

Results expressed as % and mean (SD).

Table 3 Association between insomnia and indicators of building dampness

	Insomnia (at least one symptom)	
	Crude OR (95% CI) (n = 15 785)	Adjusted OR (95% CI)* (n = 14 034)
Women	1.36 (1.27 to 1.46)	1.43 (1.31 to 1.55)
Never smoker	1	1
Ex-smoker	1.30 (1.19 to 1.42)	1.21 (1.10 to 1.34)
Current smoker	1.27 (1.17 to 1.39)	1.13 (1.03 to 1.25)
Detached house	1	1
Semi-detached	1.03 (0.92 to 1.15)	1.00 (0.88 to 1.13)
Apartment	1.25 (1.15 to 1.35)	1.25 (1.14 to 1.36)
Building dampness (at least one indicator)†	1.35 (1.23 to 1.48)	1.33 (1.21 to 1.48)
Water damage	1.25 (1.13 to 1.39)	1.26 (1.12 to 1.41)
Visible moulds	1.38 (1.21 to 1.58)	1.33 (1.14 to 1.36)
Floor dampness	1.96 (1.66 to 2.32)	1.74 (1.44 to 2.10)

Result are presented as crude and adjusted odds ratios (95% CI).
*Adjusted for centre, age, building age, body mass index, allergic rhinitis, asthma, chronic bronchitis, and the variables in the table.
†Each indicator of building dampness entered separately.

serious consequences of insomnia.[1–4] A relation between quality of sleep and building dampness has to our knowledge only been reported in one study. In that investigation Packer and co-workers reported that people living in damp buildings more often complained of perceived ill health, including problems related to poor sleep as measured by the Nottingham Health Profile.[15]

A higher prevalence of insomnia was found in subjects living in apartments compared to those living in detached houses. There are several possible explanations for this finding. The type of housing can be related to social status, and a lower social status has in some reports been related to poorer quality of sleep.[20 21] Night-time problems with disturbing noise from traffic or neighbours are probable more common for subjects living in apartments than in detached houses. It should, however, be noted that there were no significant differences between different types of housing in the association between insomnia related symptoms and building dampness, and that the relation between insomnia and building dampness remained significant after adjusting for socioeconomic status. As in several previous studies we found that insomnia related symptoms were more common in women than in men,[1 22–24] and more frequent in smokers than non-smokers.[1 25]

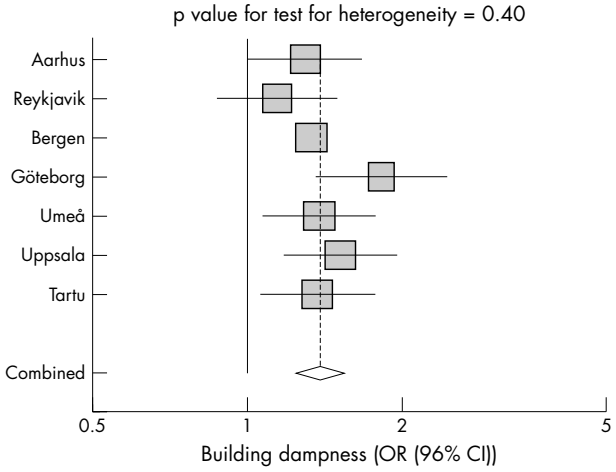

Figure 2 Adjusted odds ratios and 95% CIs of insomnia related symptoms at least three nights per week in subjects living in homes with reported building dampness compared to subjects living in homes without building dampness (adjusted within centre for age, sex, smoking history, type of housing, and age of home) with a combined odds ratio (diamond indicates 95% CI) from the model with centre as the random effect. The size of each square is proportional to the sample size.

In contrast to the lack of studies on the association between quality of sleep and the indoor environment, there is a large amount of evidence showing a relation between respiratory disorders and building dampness.[12 13] In our analysis the association between insomnia and building dampness remained significant after adjusting for respiratory disorders such as asthma, rhinitis, and chronic bronchitis, indicating that this association can only partially be explained by the known association between building dampness and airway diseases. The relation between insomnia and building dampness also remained significant after adjusting for other indicators of respiratory health, such as wheeze or the number of respiratory infections in the past 12 months (data not shown).

There are different mechanisms that could explain the observed association between insomnia and building dampness. House dust mites thrive in a humid environment. The presence of house dust mite and sensitisation to mites are, however, lower in Northern Europe than in regions with a warmer climate.[26 27] It is therefore less likely that exposure to house dust mites explains the relation between dampness and insomnia in our investigation. Moulds thrive in damp environments, and it has been shown that persisting water damage for more than three days increases the indoor levels of spores.[28] The major structural components of fungal cell wall are glucans, which can cause respiratory symptoms.[29 30] Airborne levels of β-1,3-glucan have also been associated with more general symptoms such as lethargy and fatigue.[31] Microbial indoor growth may cause an emission of volatile organic compounds (VOC) of microbial origin (MVOC).[32] Some of these compounds have a typical mouldy or pungent smell. Perception of such odours can increase the awareness of poor indoor air quality, as well as nasal and throat symptoms.[14] Building dampness may also increase the emission of VOC due to chemical degradation of building material, without microbial growth. One such example is degradation of phthalate esters, used as plasticizers in poly-vinyl-chloride (PVC) floor coatings or glues, causing an emission of the compound 2-etyl-1-hexanol to the indoor air.[33] Increased emission of VOC and MVOC in damp homes may lead to increased perception of impaired air quality and dryness in mucous membranes, resulting in sensory perceptions impairing sleep quality. In addition, dampness related exposures

Table 4 Independent association between insomnia related symptoms and indicators of building dampness

	Difficulty inducing sleep OR (95% CI)*	Difficulty maintaining sleep OR (95% CI)*	Early morning awakenings OR (95% CI)*
Building dampness (at least one indicator)†	1.30 (1.10 to 1.52)	1.33 (1.19 to 1.49)	1.23 (1.06 to 1.44)
Water damage	1.24 (1.03 to 1.48)	1.27 (1.12 to 1.36)	1.09 (0.92 to 1.30)
Visible moulds	1.33 (1.05 to 1.69)	1.32 (1.11 to 1.56)	1.37 (1.09 to 1.70)
Floor dampness	1.85 (1.42 to 2.43)	1.62 (1.32 to 1.98)	1.59 (1.22 to 2.08)

Results are presented as adjusted odds ratios (95% CI).
*Adjusted for centre, age, building age, body mass index, allergic rhinitis, asthma, chronic bronchitis, and the variables in the table.
†Each indicator of building dampness entered separately.

could cause nasal mucosal swelling and inflammation,[33–35] which in turn could impair sleep quality.

In the present study floor dampness was the dampness indicator that was most closely related to insomnia. This is to some extent in accordance with a previous study where we found that dampness in floor constructions was the dampness indicator with the strongest association to asthma.[11] Dampness in concrete floor construction is a common phenomenon in modern buildings in Northern Europe and is mainly associated with chemical degradation of building materials, not with mould growth. Increased humidity in the concrete slab causes an alkaline degradation of di-ethyl-hexylphtalate (DEHP), a plasticizer used in PVC materials, or a degradation of acrylate-polymers in water based floor glues. Both these processes lead to emission of 2-etyl-1-hexanol to the indoor environment. Increased dampness in concrete floors has been associated with nasal and throat symptoms[36] as well as increases of lysoszymes in the nasal mucosa reflecting increased inflammatory or secretory activity.[33]

An alternative explanation for the relation between insomnia and building dampness could be that subjects with insomnia are more likely to report building dampness. This explanation does, however, seem less likely, since Pirhonen *et al* found that the relation between respiratory symptoms and reported building dampness remained unchanged after adjusting for possible confounders such as socioeconomic and psychological factors.[37] Similar results have been obtained from other studies that have compared results obtained from self-reported and observed building dampness.[38 39] In our study, living in homes with building dampness was associated with a higher prevalence of other insomnia related variables such as smoking and female gender. The relation between building dampness and insomnia related symptoms did, however, remain statistically significant after adjusting for such covariates as female gender, smoking, obesity, type of housing, and respiratory disorders.

This is one of the largest population studies ever conducted to examine the prevalence of insomnia and associated risk factors. The validity of our results is also to some extent strengthened by the fact that there was no significant difference in the association between insomnia and building dampness in the different centres when this was assessed by meta-analyses. There are, however, several problems that should be taken into account when interpreting the results. The main problem is that the results are based on self-reported data. While it would have been difficult to perform such a large study with actual sleep recordings and home environment monitoring, our results should be confirmed with objective outcome measures. The second problem is related to the fact that this is a cross-sectional analysis of a follow up study. This means that even though the response rate was reasonably high in both stages, our results are based on only 60% of the original population. The response rate analysis from the present and our previous ECRHS survey has shown that men and younger subjects are slightly underrepresented.[40] As the absolute differences between non-responders and responders were relatively small, we do not think that this has affected our results substantially.

In conclusion, we found that insomnia related symptoms were more common in subjects living in damp buildings. This indicates that avoiding dampness in building constructions and improving ventilation in the homes may, in addition to improving respiratory health, also have a positive effect on quality of sleep.

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